THE EFFECT OF RAPID RAISING OF THE BOW SEAL ON EARLY TRANSITION OF THE XR-3 CAPTURED AIR BUBBLE TESTCRAFT

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THESIS

The Effect of Rapid Raising of the
Bow Seal on Early Transition of the
XR-3 Captured Air Bubble Testcraft

by

Wayne Thomas Moore

March 1976

Thesis Advisor: D.M. Layton

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The report contains a brief description of the testcraft, of the installed air spring seal, and seal position control

20. Abstract (continued)

mechanisms. A short description of the data gathering and reduction systems is also included.

The report then presents data in the form of bar graphs showing the thrust and velocity required for normal and bow-seal-raising transition. Finally, the conclusions that may be drawn from the data are presented.

The Effect of Rapid Raising of the
Bow Seal on Early Transition of the
XR-3 Captured Air Bubble Testcraft

by

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A series of tests was conducted to determine the effects of rapid raising of the bow seal on the transition of the XR-3 captured air bubbles testcraft.

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I. INTRODUCTION

Future development and growth of the United States Navy force the need for high speed surface combatants with the ability to obtain speeds in excess of fifty knots. Conventional displacement hulls, with their inherent high drag, cannot achieve this capability without the use of massive power plants. One particularly attractive alternative to conventional hull design is the surface effect ship. The U.S. Navy presently has an active program of research into the characteristics of this type of vessel. Under the sponsorship of the Surface Effects Ships Project Office (SESPO), the Naval Postgraduate School has operated the XR-3 captured air bubble testcraft in an on-going series of test programs since the summer of 1970.

The focus of this report is on one series of these tests. The purpose of these tests was to determine the effect of bow seal movement during transition upon the performance of the XR-3 testcraft. All tests were performed at the San Antonio Lake test site in California.

A. DESCRIPTION OF THE XR-3

The XR-3 testcraft operated by the Naval Postgraduate School is a captured air bubble type of surface effect ship. It has a beam of 12 feet, an overall length of 24 feet, and weighs approximately 6,000 pounds in the test configuration with a crew of two men.

The twin hull construction, similar to that of a catamaran sailing craft, is the most prominent physical feature of the testcraft. Installed between the side hulls at the bow and stern of the testcraft are flexible, inflated air spring seals. These seals, together with the side hulls, form a sealed plenum chamber beneath the testcraft. About 80% of the total testcraft weight is supported by the large aerostatic lift force created by pressurization of the plenum chamber. The remaining testcraft weight is principally supported by the displacement lift of the side hulls. The side hulls draw between two and ten inches of water, contingent upon the testcraft weight and center of gravity. The water level inside the chamber is lower than the external level, due to the pressurization of the plenum.

Five axial fans, each driven by an aircooled, internal combustion engine, pressurize the plenum chamber. The plenum is directly pressurized by two of these engines, while two more selectively pressurize the bow seal. The fifth engine is used to pressurize the rear seal.

A 110 volt, 1,500 watt a.c. generator, located on deck, aft of the lift engine compartment, provides power for the data acquisition systems.

Located on the aft end of the side hulls, outboard of the stern seal, are two 40-horsepower outboard motors that provide the propulsion for the XR-3. In order to reduce propeller side force effects to a minimum, the motors are

configured so that the port and starboard propellers rotate in opposite directions.

There are two crew member positions aboard the XR-3; the pilot controls all maneuvering and data collection functions, while the observer has no specific duties other than observation and safety.

B. THE AIR SPRING SEAL

1. Description

The XR-3 presently uses air spring seals that were installed in the winter season of 1972-73, replacing the semi-rigid seals originally provided with the testcraft. The Naval Ships Research and Development Center, CARDEROCK, Maryland designed and fabricated the new seals.

The construction of the bow and stern seals is identical, the only difference being in the rigging of the position control cables. Each seal is comprised of a two-cell rubberized fabric air bag which is attached to the underside of the plenum chamber (termed "wet deck"). Twelve steel spring stiffeners, measuring 48" x 4" x 1/4", are constructed in the lower surface of the seal to give strength and shape to the seal (see Figure 2). To provide a measure of rate damping of seal motion, the cells of the air bag are divided by a perforated fabric in order to control the rate of airflow from one cell to the other. The seals may be selectively pressurized over a range of pressures in order to obtain various spring constants.

2. Position Control Mechanism

Two downstop rings are attached to each of the steel spring stiffeners; one six inches forward of the trailing edge, and one 30 inches forward of the trailing edge.

On the bow seal, each of the forward downstop rings is connected by a steel shackle to an aluminum bar that runs across the craft's beam the full width of the seal. The aft downstop rings are attached to a second bar in an identical manner. Two steel cables connect each of these bars to an electrically operated winch. The winch capstan is divided into two sections of dissimilar diameter. The capstan section diameters were chosen so that the seal could be raised evenly, rotating about the hinge line, by winding the cables from the more forward downstops on the smaller section and the cables from the aft downstops on the larger section (see Figures 3 and 4).

C. SEAL SHAPE

Figures 5 and 6 show the contours of the seals in both the pressurized and unpressurized states. The shapes of the bow and stern seals are identical, being slightly bowed. The bowed shape of both seals becomes much more pronounced under pressurization.

II. TESTING PROCEDURE

A. GENERAL

The purpose of this series of tests was to investigate the effect of raising the bow seal upon the transition performance of the XR-3 and determine if an early transition (lower thrust and lower velocity) could be obtained. A series of test runs was conducted to determine the thrust (or drag) to velocity relationship at transition that existed with and without raising the seal. These relationships were then graphically compared to determine the effect of raising the bow seal.

B. DATA ACQUISITION

The instrumentation aboard the XR-3 is quite extensive. Sensors are installed to measure thrust, velocity, accelerations, angular displacements and rates about all axes, rudder angle, plenum and seal pressures, and height of a reference point above water. In this test series, the parameters of interest were thrust, velocity and pitch angle.

1. Thrust Measurement

To insure only readings of longitudinal forces, the thrust of each outboard motor is transmitted to a balanced-bridge load cell by a parallelogram linkage. The output of the load cell is amplified to a range of 0.0 to

1.0 volts d.c. for compatibility with the onboard tape recorder. The voltage range corresponds to a thrust range of 0 to 500 pounds.

2. Velocity Measurement

The testcraft velocity is measured by a Potter velocity meter located on a supporting strut in the undisturbed water ahead of the testcraft (see Figure 1). The meter consists of a small magnetized free turbine in an axial duct contained in a bomb-shaped probe. The rotating turbine wheel induces a sinusoidal voltage in a pickup coil located in the probe body. The signal frequency is directly proportional to flow through the meter, thus to the testcraft velocity. A velocity conditioning unit consisting of a frequency to voltage converter, provides a signal of 0.0 to 5.0 volts d.c. that corresponds to testcraft velocities of 0 to 40 knots. This signal is split, one branch being reduced in voltage to 0.0 to 1.0 volts d.c. for compatibility with the data recording equipment. The other signal branch drives a d.c. voltmeter, that has been calibrated in knots, located on the pilot's instrument panel.

3. Pitch Angle Measurement

The Pitch Angle was measured using the Humphrey's Model CF18-0101-1 gyro package which is capable of measuring pitch, roll and yaw displacement and pitch, roll and yaw rates.

4. Data Recording

A Pemco model 120 magnetic tape recorder automatically records all data taken onboard the XR-3. The tape recorder simultaneously records fourteen channels of data from the electronic sensors and, in addition, the comments and observations of the pilot on a voice edge track. Recording accuracy is 1/2% for an input range for each channel of -1.0 to +1.0 volts d.c. The Pemco recorder, located in a compartment aft of the pilot's cockpit, is controlled by means of a remote control system on the pilot's instrument panel. The 26 volt d.c. power required by the recorder is provided by a Pemco power supply which obtains its power from the 110 volt d.c. generator. A digital voltmeter connected to the data inputs through a rotary selector switch enables the pilot to monitor the input to any channel. The Pemco recorder is easily portable, thus it can be taken out of the XR-3 to the Mobile Data Facility, where data may be immediately reduced and analyzed, at the completion of each day's operation. Reference 1 provides additional information on the data collection and recording system.

C. DATA REDUCTION

The XR-3 Mobile Data Facility is contained in a 26-foot Champion motor home. A part of the interior furnishings have been removed and a complete data reduction system has been installed. The motor home also provides berthing and messing for XR-3 personnel during extended operations, in

addition to the data reduction facilities and working space. The mobile facility supplies power for the data systems from a self-contained gasoline-powered 110 volt, 5,000 watt a.c. generator. A Pemco power supply is used to provide power to the tape recorder, while all other equipment uses the 110 volt a.c. power directly.

The data reduction equipment, in addition to the tape recorder, consists of:

1. Signal selector and conditioning unit
2. Analog to digital converter and calculator interface module
3. Monroe model 1880 calculator
4. Monroe model PL-4 digital X-Y plotter
5. Hewlett-Packard model 7100-B two-channel strip chart recorder

The signal selector and conditioning unit is of major importance to the data reduction system. It conditions the raw analog data from the tape recorder to supply the proper signals to the strip chart recorder and to the Monroe calculator for display on the Monroe X-Y plotter. All fourteen channels of raw analog data on the tape recorder are accepted by the signal conditioning unit. The operator may output any given parameter on any of nine output channels through the use of a selector panel. A summing circuit is also provided which combines the port and starboard thrust signals to provide a total thrust signal. The unit also filters out high-frequency noise from the data and provides

a means for adjusting the null and range of the conditioned output. The strip chart recorder displays any two channels of analog data. For further calculations on the Monroe calculator or plotting on the X-Y plotter, the conditioned analog data may also be converted to digital form. A complete description of the data reduction system may be found in reference 2.

D. TEST RUNS

1. General

The test runs were conducted so as to obtain thrust, velocity and pitch angle during transition both without raising and with raising the bow seal at several seal positions. The weight and center of gravity of the testcraft were held constant as possible during the runs.

Before conducting the test series, the date, crew, data channelization, weight, and center of gravity were annotated on the voice track of the tape recorder. All channels were calibrated to enable accurate setting of the null and range on the data reduction equipment. The thrust load cells had known loads of 0, 250, and 500 pounds applied, and a zero velocity signal was recorded. Once upon the water, a twenty-knot velocity calibration was conducted and recorded.

Prior to each test run, the pilot prefaced the tape with the known data for that run. This included seal

position, weight, center of gravity, and factors that may affect the conduct of the test such as wind and sea conditions.

All tests were conducted in calm water conditions, and, as nearly as possible, in calm wind conditions. Due to the size of the XR-3, aerodynamic drag forces, though unknown, are certainly significant. In order to minimize any variations in aerodynamic drag between upwind and downwind runs, tests were held only under very light wind conditions.

2. Normal Transition Procedure

With the testcraft in a stopped position, engines at idle, both seals were set at minimum pressurization and plenum pressure set at 23.5 pounds per square foot. Power was then added slowly, while maintaining heading with rudder, until transition over the secondary hump occurred. Thrust, velocity and pitch angle were continuously recorded during each run.

3. Bow-Seal-Raising Transition Procedure

Seal and plenum pressure were set as in the normal transition procedure. Power was added slowly until the velocity was just below that for transition. As velocity increases, the air venting under the side walls moves aft and at the transition point this venting is approximately even with the blower engine compartment. The addition of power is halted at this point, prior to transition, and held

steady to ascertain that the testcraft is in fact below transition. Once this is confirmed, the bow seal is raised electrically by means of an "up" switch in the cockpit. Heading is held steady with rudder while the testcraft transitions over the secondary hump.

In runs 4601 through 4607, the trailing edge of the bow seal was raised two inches above the skeg keel, and the position of the forward downstop varied as in runs 4501 through 4505. This was done in an attempt to investigate the effects of the bow raising transition procedure with a more rounded trailing edge shape.

The data from these runs are shown in Table I.

It was desired to make additional runs to validate the data, but this was precluded by a gross failure of the bow seal retraction mechanism in December 1975. Due to the urgency of installing a modified rear seal support system, the XR-3 was removed from service temporarily in January 1976 and no time was available for additional runs.

III. RESULTS

Figures 8 through 16 present the data in the form of bar graphs, collected from the test series. Each bar graph relates thrust and velocity during transition for both the normal and bow-seal-raising procedures. Figure 17 shows the pitch angle of the testcraft with time.

Upon examination of the graphs, the following may be observed:

1. In runs 4501 through 4505 (Figures 8 through 11): There is a marked improvement in both thrust and velocity for transition with the bow-seal-raising procedures. No effect is observed with the bow seal in the relaxed position, but as the center downstop position is raised, an increased improvement is observed, in both thrust and velocity, until an optimum is reached around a downstop position of 0.68 inches. After this, the effect of raising the bow seal for transition is decreased and approaches the thrust and velocity levels required for normal transition.

2. In runs 4601 through 4607 (Figures 12 through 16): The thrust required for transition is less than that of the 4500 series runs, yet follows the same general pattern. There is still an improvement by use of the bow-seal-raising procedure, but not as marked as the

4500 series runs. The optimal bow-seal-raising transition occurs at a downstop position of 0.51 inches. Velocity at transition is also less than the normal transition and follows the pattern of thrust improvement.

Qualitative tests with rapid raising and lowering of the bow seal effected transition in the same manner as though the bow seal were raised and not lowered. Approximately 2 seconds are required for the seal to go from full down to full up, and approximately 1.5 seconds from full up to full down positions. The testcraft begins to dip (nose down pitch) at the moment the seal begins to raise, but almost immediately pitches up and transitions.

In general, the bow-seal-raising procedure does effect an early transition provided the seal shape is not flattened beyond the optimal. Reference 4 provides information on seal shape variations. The bow-seal-raising procedure produces more dramatic lowering of thrust and velocity with the bow seal trailing edge in the full down, unrestrained position.

IV. CONCLUSIONS

From the data presented, the following conclusions have been drawn:

1. It is possible to effect an early transition (lower thrust and lower velocity) by raising the bow seal, provided the seal shape is optimal (see Reference 4).

2. With the bow seal in the relaxed position, raising the bow seal does not permit overriding the bow wave. However, as the seal shape is flattened by pulling up on the center downstop, raising the bow seal effects an early transition.

3. If the bow seal shape is flattened beyond the optimum shape, the early transition is "delayed" and approaches the normal transition as a limit.

4. Positioning of the static seal shape with respect to the sidewall (raising the trailing edge as in the 4600-series runs) although providing a general improvement in thrust required for transition, does not create as dramatic an improvement in the bow-seal-raising mode as it did in the 4500 series runs.

TABLE I

Run N°	Center Downstop Position (Inches from relaxed position)	Thrust* (lbs)	Velocity* (kts)	Θ_{ss} (Deg)	Thrust# (lbs)	Velocity# (kts)	Θ_{min} (Deg)
Bow Seal - Trailing Edge at Skeg Keel, Minimum Pressure Rear Seal - Relaxed, Minimum Pressure							
4501	0.00	395	6.0	2.1	395	6.0	2.1
4502	0.25	392	5.8	2.1	385	5.3	1.4
4503	0.51	510	6.0	2.1	375	5.2	1.1
4504	0.68	415	6.1	2.1	375	5.2	1.1
4505	1.00	395	6.0	2.2	380	5.9	1.4
Bow Seal - Trailing Edge 2 Inches Above Skeg Keel, Minimum Pressure Rear Seal - Relaxed, Minimum Pressure							
4601	0.00	330	6.0	1.8	330	6.0	1.8
4602	0.25	357	6.0	1.9	351	5.8	1.6
4603	0.37	368	6.0	1.9	350	5.3	1.1
4604	0.51	330	6.0	1.9	320	5.2	1.2
4605	1.00	345	6.0	2.0	342	5.9	1.8

* Normal Transition - Secondary Hump Maximum Value

Raising Bow Seal - Secondary Hump Maximum Value

Θ_{ss} - Steady State Pitch Angle - Normal Transition

Θ_{min} - Minimum Pitch Angle - Raising Bow Seal

Weight 6010 pounds

Center of Gravity 119 in.

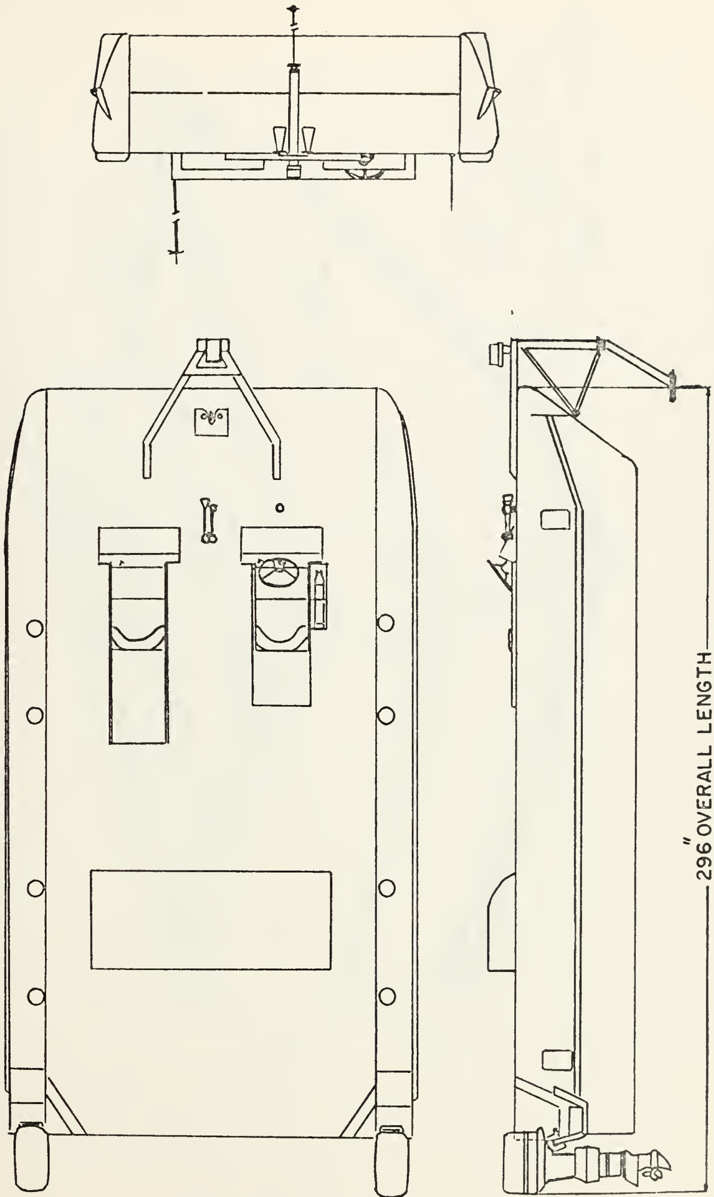
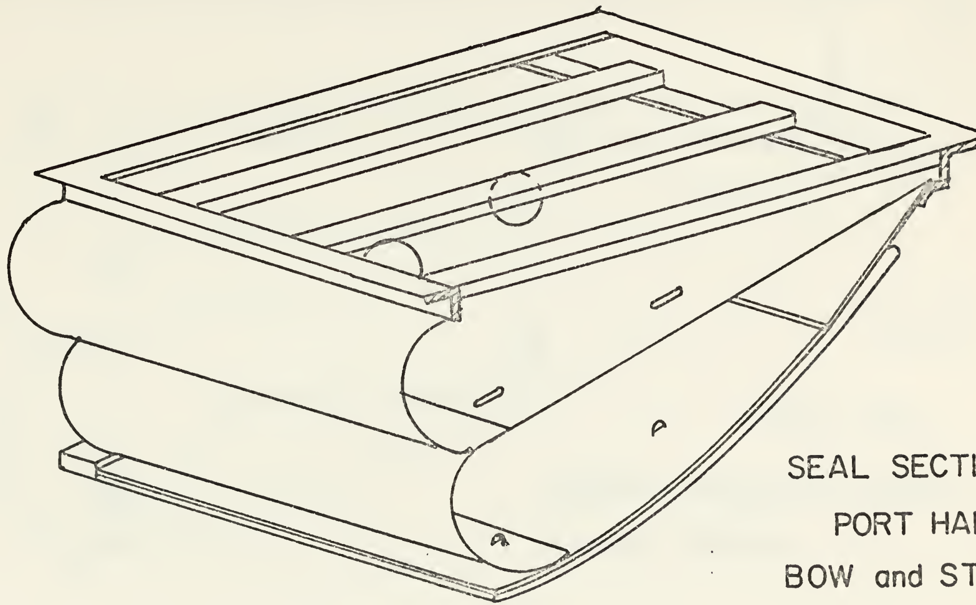


Figure 1: General Configuration of the XR-3



SEAL SECTION
PORT HALF
BOW and STERN

Figure 2

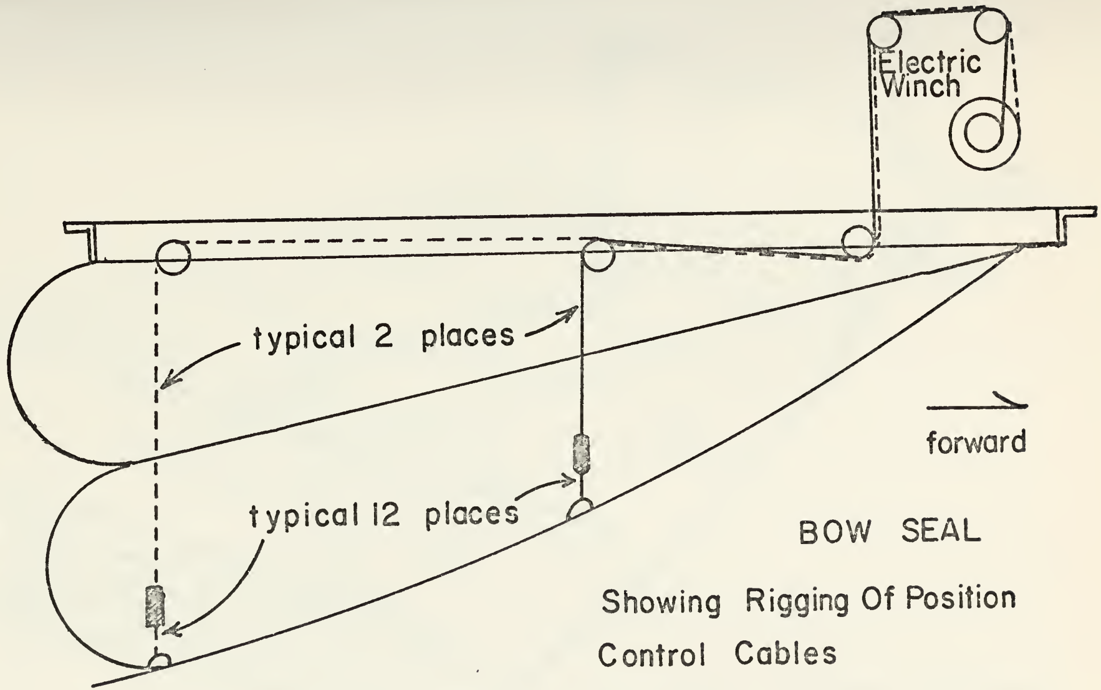
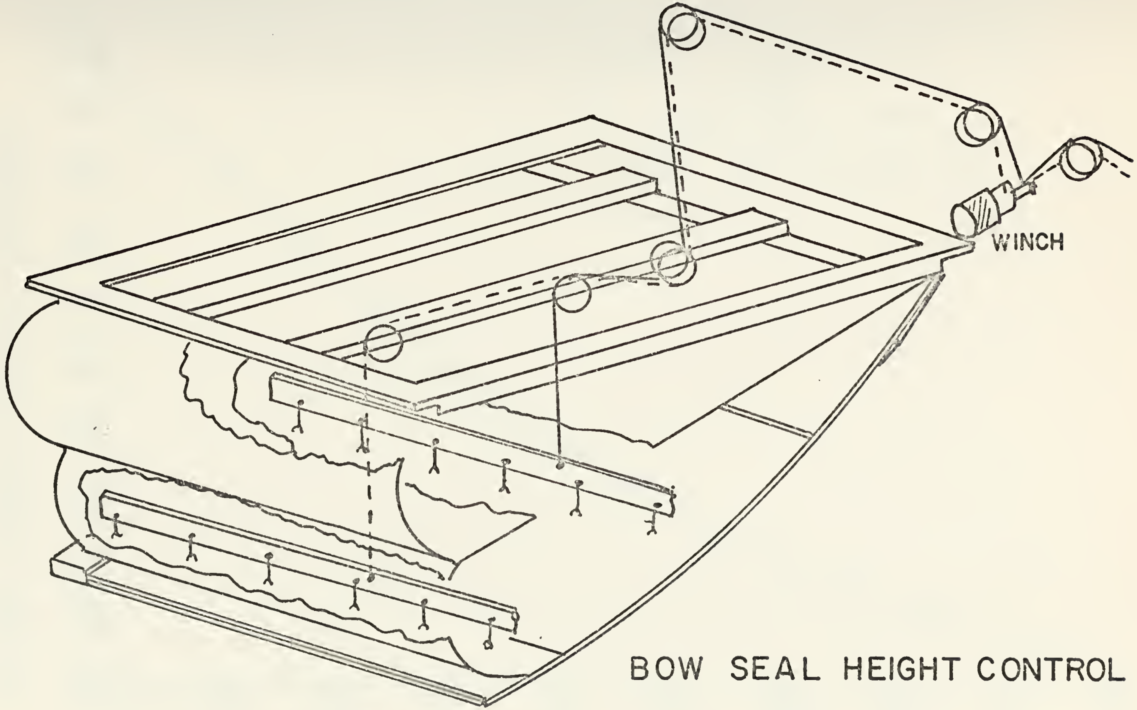

Electric
Winch
typical 2 places
typical 12 places
forward
BOW SEAL
Showing Rigging Of Position
Control Cables

Figure 3



BOW SEAL HEIGHT CONTROL

PORT HALF

Figure 4

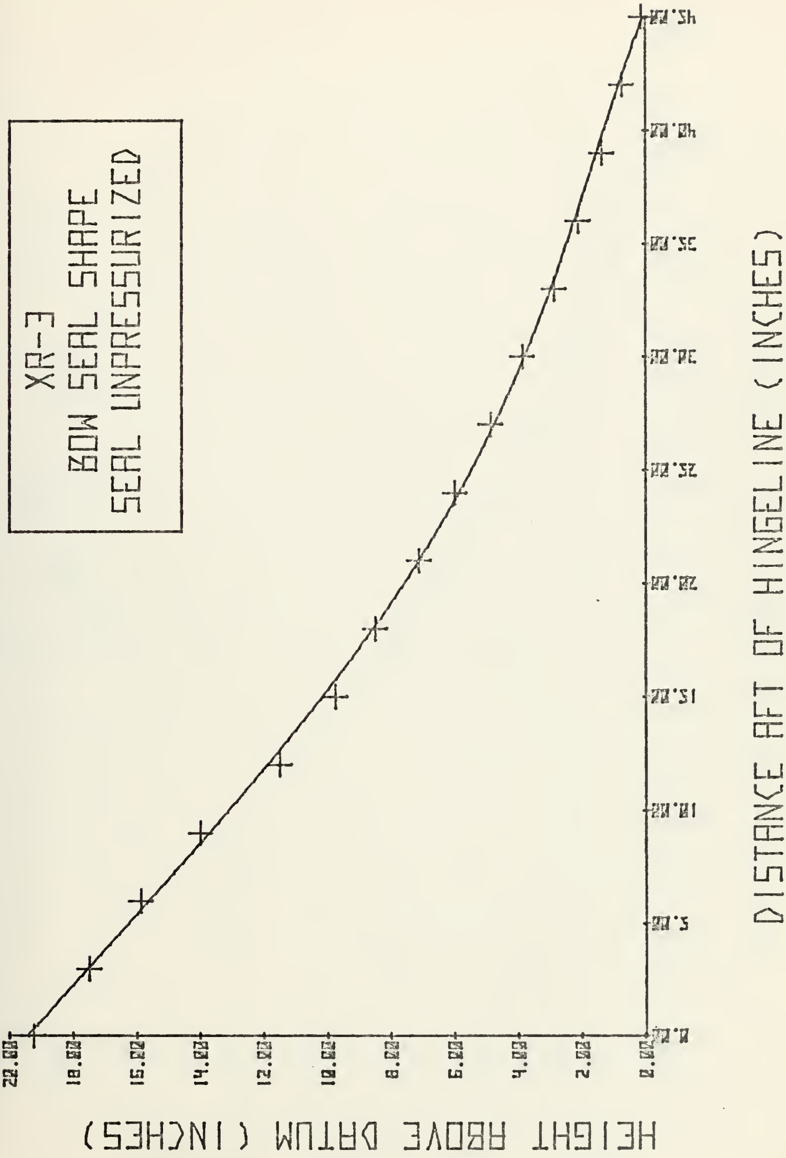

XR-3
BOW SEAL SHAPE
SEAL UNPRESSURIZED
HEIGHT ABOVE DATUM (INCHES)
DISTANCE AFT OF HINGELINE (INCHES)
0.00
2.00
4.00
6.00
8.00
10.00
12.00
14.00
16.00
18.00
20.00
5.00
10.00
15.00
20.00
25.00
30.00
35.00
40.00
45.00

Figure 5

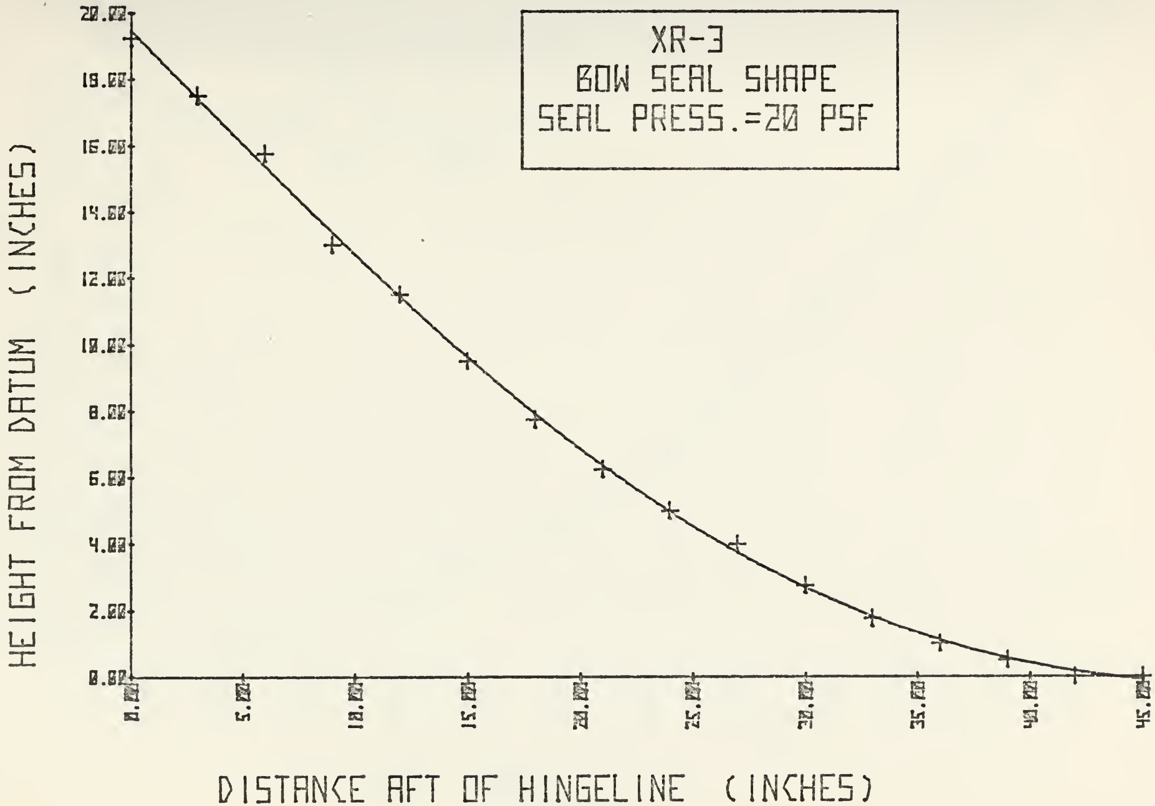

XR-3
BOW SEAL SHAPE
SEAL PRESS.=20 PSF
HEIGHT FROM DATUM (INCHES)
DISTANCE AFT OF HINGELINE (INCHES)
0.00
2.00
4.00
6.00
8.00
10.00
12.00
14.00
16.00
18.00
20.00
5.00
10.00
15.00
20.00
25.00
30.00
35.00
40.00
45.00

Figure 6

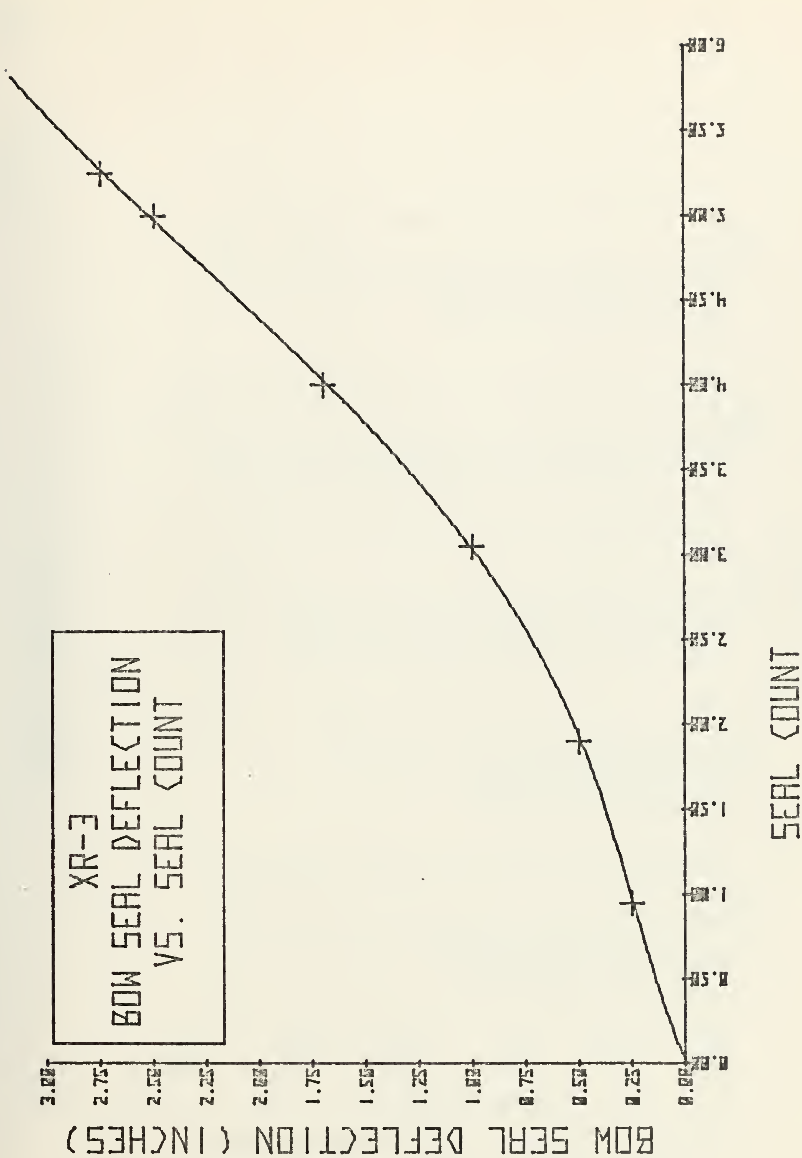

XR-3
BOW SEAL DEFLECTION
VS. SEAL COUNT
BOW SEAL DEFLECTION (INCHES)
0.00
0.25
0.50
0.75
1.00
1.25
1.50
1.75
2.00
2.25
2.50
2.75
3.00
SEAL COUNT
0.00
0.50
1.00
1.50
2.00
2.50
3.00
3.50
4.00
4.50
5.00
5.50
6.00

Figure 7

NORMAL TRANSITION
BOW SEAL TRAILING EDGE FULL DOWN

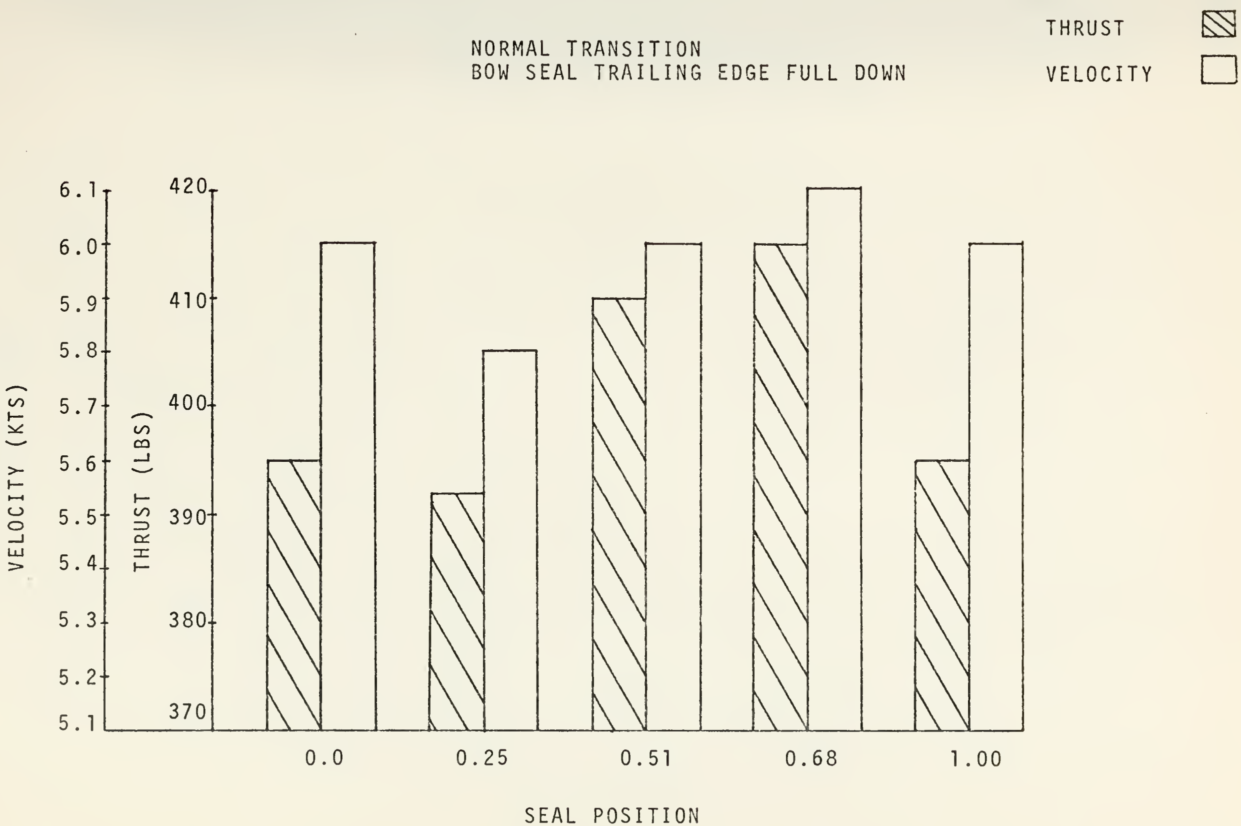


FIGURE 8

BOW-SEAL-RAISING TRANSITION
BOW SEAL TRAILING EDGE FULL DOWN

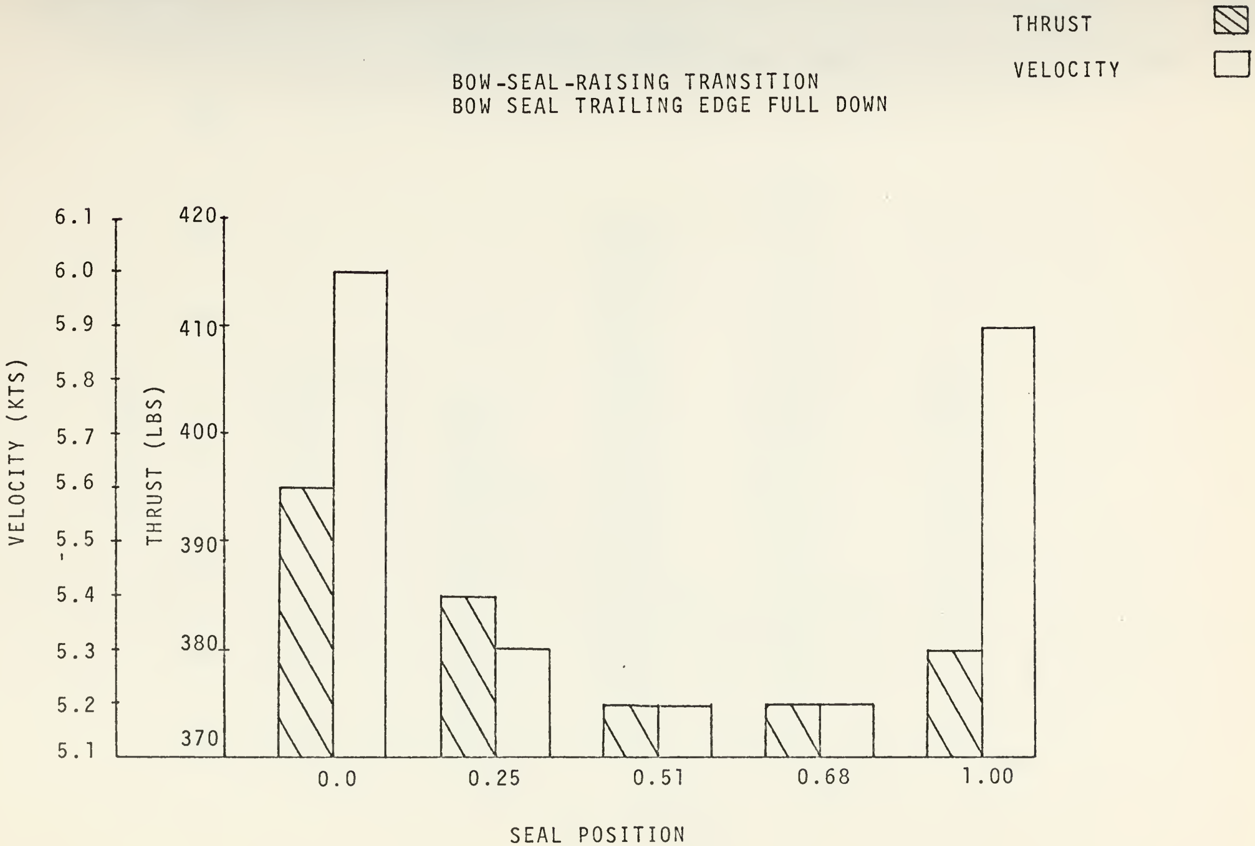


FIGURE 9

COMPARISON OF THRUST
BOW SEAL TRAILING EDGE FULL DOWN

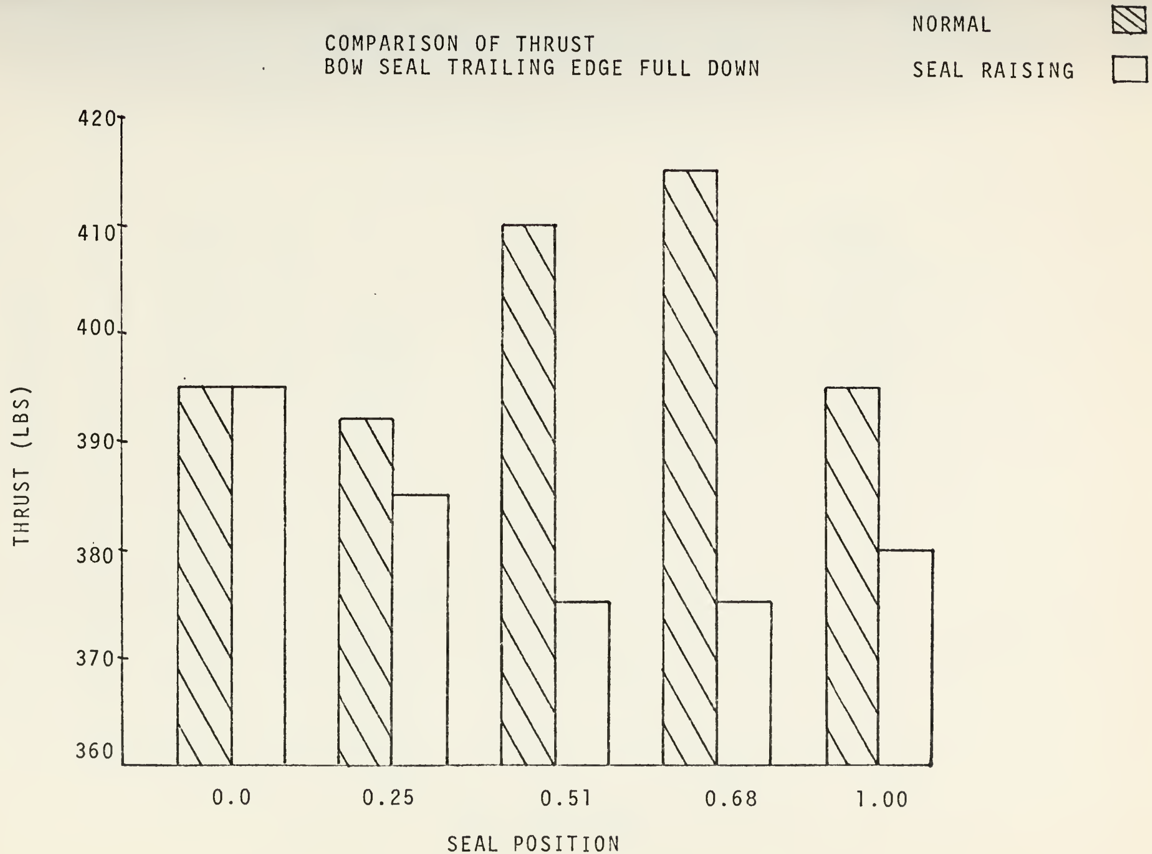


FIGURE 10

COMPARISON OF VELOCITY
BOW SEAL TRAILING EDGE FULL DOWN

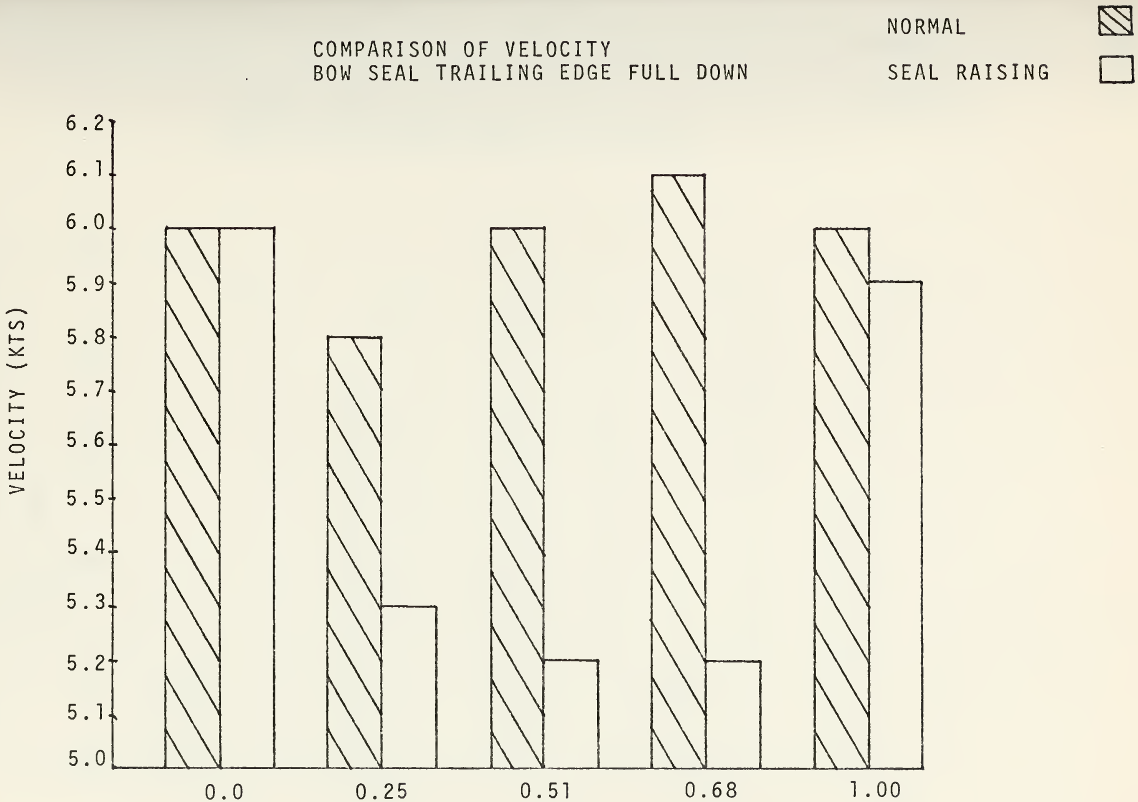


FIGURE 11

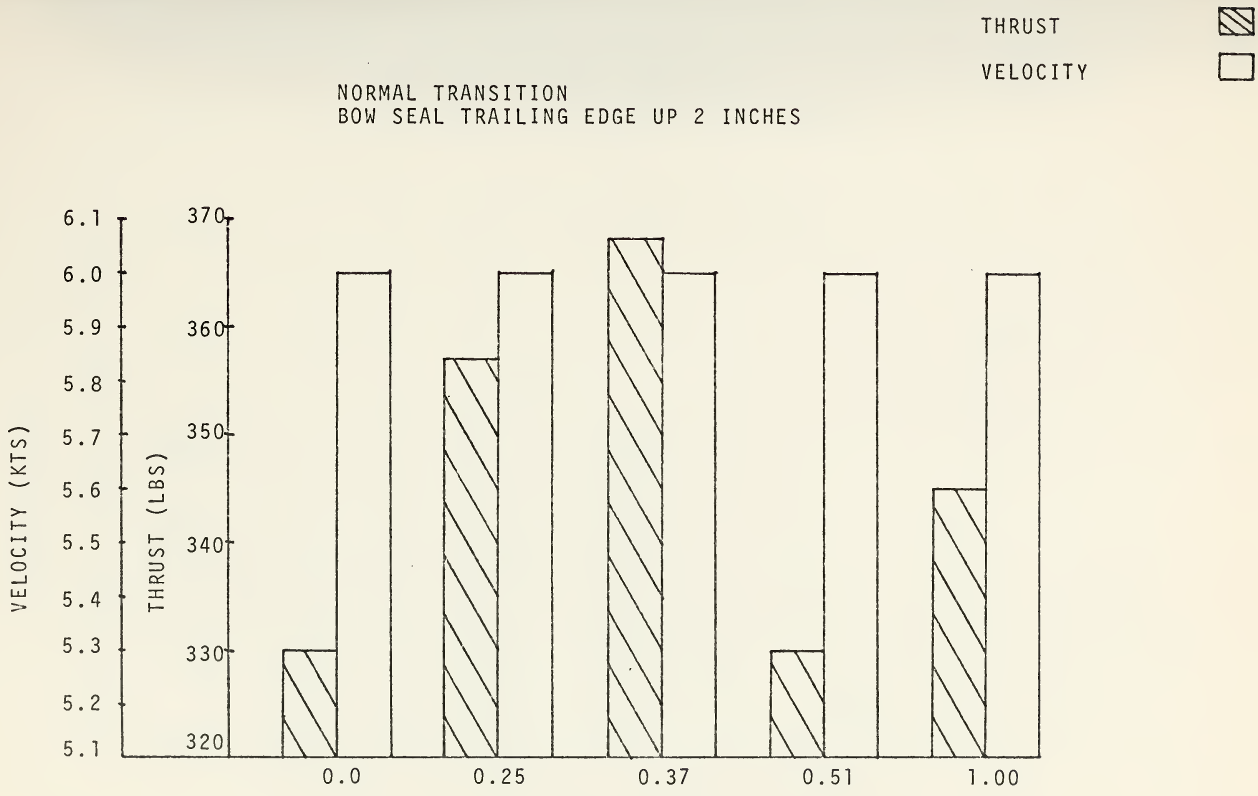

THRUST
VELOCITY
NORMAL TRANSITION
BOW SEAL TRAILING EDGE UP 2 INCHES
VELOCITY (KTS)
6.1
6.0
5.9
5.8
5.7
5.6
5.5
5.4
5.3
5.2
5.1
THRUST (LBS)
370
360
350
340
330
320
0.0
0.25
0.37
0.51
1.00
SEAL POSITION

FIGURE 12

BOW-SEAL-RAISING TRANSITION
BOW SEAL TRAILING EDGE UP 2 INCHES

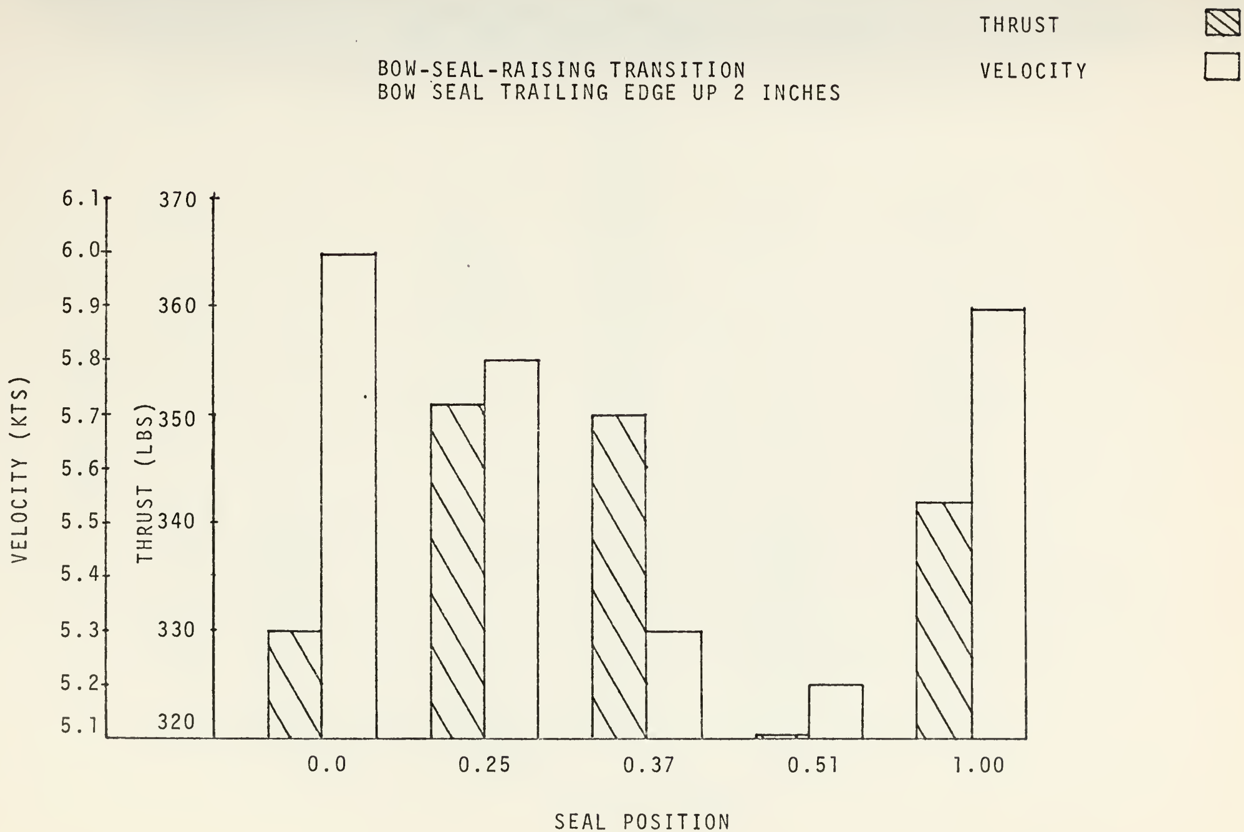
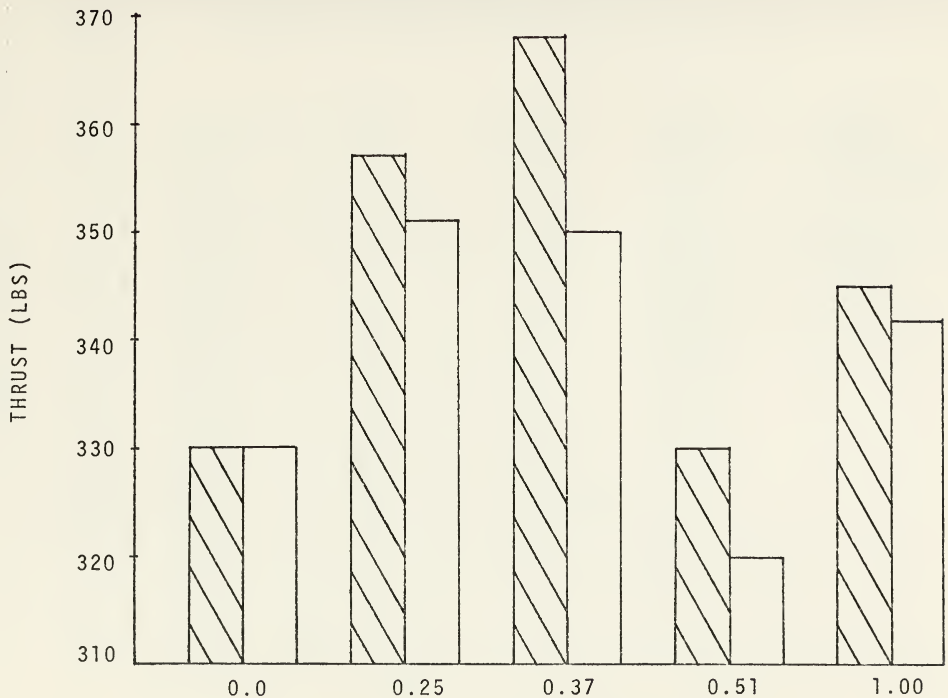


FIGURE 13

COMPARISON OF THRUST
BOW SEAL TRAILING EDGE UP 2 INCHES

NORMAL

SEAL RAISING



SEAL POSITION

FIGURE 14

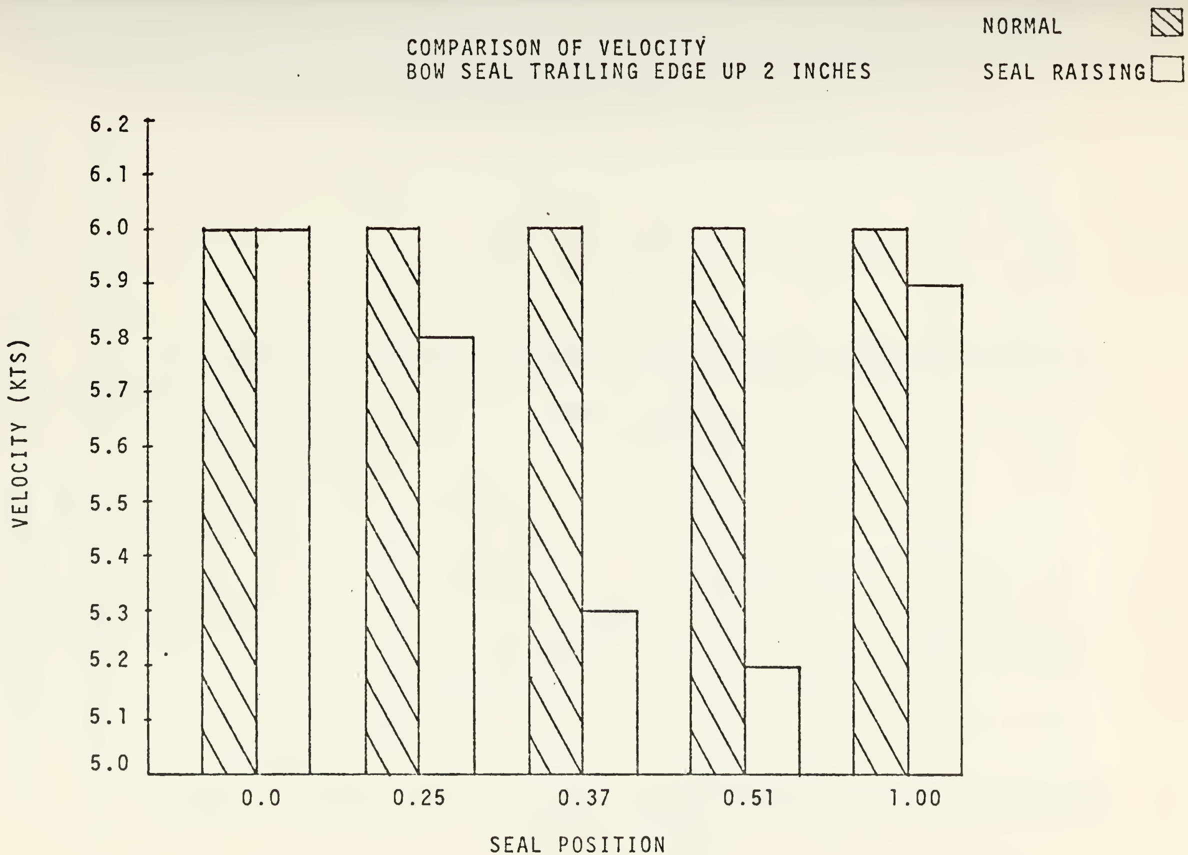

COMPARISON OF VELOCITY
BOW SEAL TRAILING EDGE UP 2 INCHES
NORMAL
SEAL RAISING
VELOCITY (KTS)
6.2
6.1
6.0
5.9
5.8
5.7
5.6
5.5
5.4
5.3
5.2
5.1
5.0
0.0
0.25
0.37
0.51
1.00
SEAL POSITION

FIGURE 15

PITCH ANGLE VS TIME

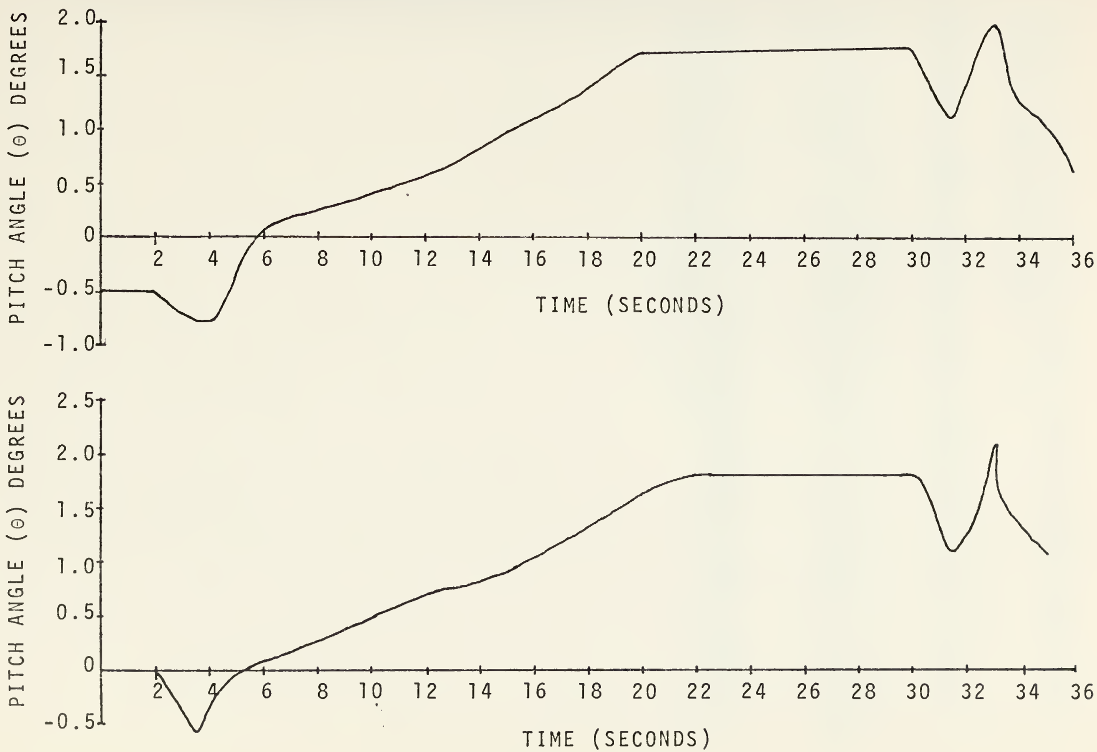


FIGURE 16

LIST OF REFERENCES

1. Feeney, James Leo, XR-3 Data Acquisition System for Performance Evaluation, M.S. Thesis, Naval Postgraduate School, Monterey, March 1972.

2. Dabberi, Peter Vincent Jr., Data Reduction System for the XR-3 Captured Air Bubble Testcraft, M.S. Thesis, Naval Postgraduate School, Monterey, December 1973.

3. O'Malley, John Francis, and Belden, William Ellsworth, Jr., Design Modification and Preliminary Performance Evaluation of the XR-3, A Captive Air Bubble Testcraft. M.S. Thesis, Naval Postgraduate School, Monterey, June 1973.

4. Moloney, Robert William, The Effect of Seal Shape Variations Upon the Performance of the XR-3 Captured Air Bubble Testcraft, M.S. Thesis, Naval Postgraduate School, Monterey, March 1975.

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Moore
The effect of rapid raising of the bow seal on early transition of the XR-3 captured air bubble testcraft.